

Diet Composition of the Salamander *Lyciasalamandra luschani basoglui* on the Greek Island of Kastellorizo in the Southeast Aegean Sea

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Abstract The diet composition of the Lycian salamander *Lyciasalamandra luschani basoglui* across both age and sex groups was studied. Specimens were collected from a small island in the Southeast Aegean Sea. The dominant prey group of juveniles consisted of Collembola, while Coleoptera dominated the diet of males and females. The number and size of prey items consumed by males and females of *L. luschani basoglui* were quite similar, while juveniles ate fewer items of much smaller size. The numerical abundance along with the four measures of the size of prey permitted discrimination among males, females and juveniles. Although discrimination between adults and juveniles is expected due to dissimilarity in body size, discrimination between males and females remains inexplicable despite their similarity in body size. Future studies should be focused on understanding how and why prey choice differs between sexes in *L. luschani basoglui*.

Keywords Lycian salamander, prey item, invertebrate, Southeast Greece, age and sex groups

1. Introduction

The Lycian salamander *Lyciasalamandra luschani basoglui*, formerly *Mertensiella luschani* (Veith and Steinfartz, 2004), is found on the small Greek island of Kastellorizon in the Southeast Aegean Sea and also on the southern Turkish coast. Kastellorizon is included in the Greek list of Sites of Community Importance (SCI) of the European Ecological Network Natura 2000. The Lycian salamander is a strictly terrestrial, viviparous salamander living in a typical dry Mediterranean low shrubland habitat (phrygana) in the absence of any running or stagnant water. It is active and quite abundant during the wet period of the year, which lasts from November to April in Mediterranean Type Ecosystems. This species is

mostly nocturnal, but active during windless days with a minimum relative humidity of approximately 60%, as well as during rainy days. Throughout the dry season, areas with loose substrate and limestone crevices are preferred, providing moist shelters (Polymeni, 1994). According to the Red Data Book of Threatened Animals of Greece (2009), *L. luschani basoglui* is classified as vulnerable [VU (D2)], while in the Red Data Book of IUCN the species is considered endangered (EN). Additionally, the Lycian salamander is included in the list of Annex II of Directive 92/43/EEC and in the list of Annex II of Bern Convention. In Greece, it is also protected by the Presidential Decree 67/1981.

This study aimed to investigate the diet of males, females and juveniles of the protected salamander *L. luschani basoglui* living in an arid insular site included in Natura 2000 European Network. This publication, being the first part of a comprehensive study about *L. luschani basoglui*, is due to our concern about the survival of the animal given the isolation of the subspecies and the constant threat caused by human activities mainly by

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the touristic overdevelopment of the island in the last 20 years.

2. Methods

Due to conservation status and the legal protection of *L. luschani basoglui* only twenty nine specimens (14 males, 9 females and 6 juveniles) were collected from Kastellorizo during the period from mid-November to mid-December in 2000. The island of Kastellorizo (with an area of approximately 10 km²) is covered by phrygana, *Genista acanthoclada* and *Corydorthymus capitatus* being the dominant phryganic species, small cultivated fields and abandoned farmland. The specimens were collected from all the habitats mentioned above.

Four morphometric variables were measured on the collected specimens, body weight, body length, snout-vent length and head width (hereafter BW, BL, SVL and HW, respectively), and statistically analyzed by Kruskal-Wallis one way analysis of variance and multiple comparison tests. Salamander stomachs were flushed (Griffiths, 1986) and the contents stored in 70% glycerine alcoholic solution (70% v/v ethanol, 25% v/v water and 5% v/v glycerine).

Prey items from each stomach were counted, measured (with an ocular micrometer) and finally, except for Nematoda, Oligochaeta and Gastropoda, identified to order level. The volume of each prey item was estimated using the formula for an ellipsoid (Dunham, 1983), that is, $V = 4/3 \times \pi \times W^2/4 \times L/2$, where W = prey width and L = prey length. Being disarticulated, due to partial digestion, prey items were identified by comparison with other integral items of the same taxon.

The overall diet composition of the *L. luschani basoglui* males, females and juveniles was described by the relative abundance (RA, %) and the volumetric percentage (V, %) of prey taxa as well as by the frequency (F, %) (i. e., the percentage of stomachs containing each prey taxon). The importance (I) of each prey taxon in the diet of the three groups of this salamander was determined using formula $I = (RA\% + F\% + V\%)/3$ (Biavati *et al.*, 2004). This is an index providing a more informed assessment of overall diet composition than any of the three components alone. The Kruskal-Wallis one way analysis of variance was used to detect any difference in the overall diet composition among males, females and juveniles due to the above-mentioned variables (i. e., RA, V, F and I).

A single regression was performed on snout-vent length (SVL) and mean prey length (MPL) and mean prey volume (MPV), as well as on head width (HW), and the

latter two prey variables of the salamander were done in order to detect the prey size preference.

A further analysis of the diets of different age and sex groups of *L. luschani basoglui* was performed using discriminant function analysis (DFA) and another set of prey variables. The variables used in DFA were the abundance (A) of each prey taxon and four measures of the actual prey size, that is, total prey volume (TPV), MPV, maximum prey length (MxPL) and MPL of each prey taxon recorded in the stomach of each of the twenty nine salamander specimens. The significance of the overall discriminatory power of the analysis was tested using the “Wilks” lambda standard statistics. The standardized coefficients for canonical variables were studied to examine each variable’s contribution in the discriminant function.

Statistical analysis was performed using the statistical package Statistica 7 for Windows.

3. Results

Morphometric variables of the collected specimens as well as the results of their statistical analysis are shown in Table 1. Statistically significant differences in all the variables examined were found between adults and juveniles. On the contrary, no differences existed between males and females since their sizes were quite similar except a slight non-significant difference in body weight as females were heavier than males.

No stomach of the 29 specimens of *L. luschani basoglui* was empty and a total of 445 prey items were counted from the stomachs of all the examined animals. These prey items belonged to twenty taxa (Table 2). Males, females and juveniles ate twenty, nineteen and thirteen prey taxa, respectively.

Mean number of prey items per male was 16.90 ± 7.75 , per female 16.67 ± 6.10 and per juvenile 9.83 ± 6.68 . MPL per male was 3.92 ± 1.28 mm, per female 3.66 ± 1.13 mm and per juvenile 2.16 ± 0.41 mm. Finally, mean prey volume per male was 7.09 ± 4.78 mm³, per female 7.40 ± 8.09 mm³ and per juvenile 0.83 ± 0.40 mm³.

Importance index (I; Table 2) shows that the dominant prey groups ($I > 40.00$) of the diet of juveniles are Collembola and Gastropoda, while Hymenoptera and Coleoptera dominate the diet of females and Coleoptera is dominant in the diet of males.

However, no statistically significant differences were found in the overall diet composition among male, female and juvenile specimens of *L. luschani basoglui* concerning relative abundance [$H(2, n = 69) = 3.202609$,

Table 1 Morphometric variables of males, females and juveniles of *L. luschani basoglui* from Kastellorizo (southeast Aegean Sea, Greece) and the results of their statistical analysis.

	BW (g)	BL (cm)	SVL (cm)	HW (cm)
Female	5.40 ± 0.90	11.61 ± 0.77	6.63 ± 0.49	1.22 ± 0.06
Male	4.95 ± 0.71	11.65 ± 0.66	6.65 ± 0.31	1.19 ± 0.04
Juvenile	1.47 ± 0.25	7.68 ± 0.50	4.43 ± 0.31	0.79 ± 0.04
Kruskall - Wallis (n = 29)	H = 14.65547 P = 0.0007	H = 13.83749 P = 0.0010	H = 13.86895 P = 0.0010	H = 14.44403 P = 0.0007
Multiple comparison				
Female - male	P = 1.000000	P = 1.000000	P = 1.000000	P = 1.000000
Female - juvenile	P = 0.000709	P = 0.003699	P = 0.003542	P = 0.000901
Male - juvenile	P = 0.004410	P = 0.001449	P = 0.001496	P = 0.003799

Note: BW: Body weight; BL: Body length; SVL: Snout-vent length; and HW: Head width

$P = 0.2016$], frequency [H (2, n = 69) = 3.827729, $P = 0.1475$], volumetric percentage [H (2, n = 69) = 1.828953, $P = 0.4007$] and index of importance [H (2, n = 69) = 3.570748, $P = 0.1677$] of prey taxa.

The results derived from the single regression show that the SVL of *L. luschani basoglui* strongly predicts mean prey length [$R^2 = 0.995$ (1, 28), $P < 0.001$] and mean prey volume [$R^2 = 0.903$ (1, 28), $P < 0.001$]. A

strong prediction of mean prey length [$R^2 = 0.944$ (1, 28), $P < 0.001$] and mean prey volume [$R^2 = 0.899$ (1, 28), $P < 0.001$] derives as well from head width.

Discriminant function analysis (DFA) based on the abundance of each prey taxon and four measures of the actual prey size yielded three highly significant functions (roots) [Wilk's lambda = 0.06785, $F_{16,38} = 6.7431$, $P < 0.0000$].

Table 2 Parameters of overall diet composition of age and sex groups (n = 29) of *L. luschani basoglui* from Kastellorizo (southeast Aegean Sea, Greece)

Prey taxa	Relative abundance (%)					Frequency (%)			Volume (%)			Index of importance		
	MF	MM	MI			MF	MM	MI	MF	MM	MI	MF	MM	MI
Nematoda	1.3	2	-	-		22	-	-	0.01	-	-	7.77	-	-
Oligochaeta	-	0.4	1	-		-	7.1	-	-	-	-	-	2.5	-
Gastropoda	2	3	-	11.9	7	33	-	83.3	2.63	-	38.32	12.54	-	44.51
Araneae	6	9	6.6	15	8.5	5	44	42.9	67.7	1.89	6.65	19.08	17.29	18.18
Pseudoscorpionida	5.4	8	9.3	21	3.4	2	66	64.2	33.3	1.69	1.87	4.42	24.36	25.12
Phalangida	-	1.3	3	3.4	2	-	14.3	33.3	-	0.28	-	-	5.29	12.23
Acarina	4	6	3.1	7	-	33	50	-	3.54	1.02	0.74	13.51	18.04	0.24
Isopoda	0.7	1	1.3	3	-	11	21.4	-	1.59	-	-	3.9	7.57	-
Iulida	0.7	1	1.8	4	1.7	1	11	14.3	16.7	1.59	7.81	0.87	4.43	7.97
Geophilomorpha	-	1.3	3	1.7	1	-	14.3	16.7	-	3.09	-	-	6.23	6.13
Thysanura	0.7	1	2.2	5	1.7	1	11	28.6	16.7	0.44	0.1	-	4.04	10.3
Collembola	7.4	11	10.1	23	54.2	32	55	71.4	83.3	0.39	0.17	7.76	20.93	27.22
Orthoptera	0.7	1	-	-		11	-	-	11.67	-	-	7.79	-	-
Embioptera	0.7	1	0.4	1	-	11	7.1	-	-	-	-	3.9	2.5	-
Hemiptera	5.4	8	1.3	3	-	44	14.3	-	7.94	2.22	-	19.11	5.94	-
Diptera	6	9	5.7	13	3.4	2	55	71.4	16.7	5.1	3.48	5.55	22.03	26.86
Hymenoptera	20.8	31	8.8	20	-	88	64.3	-	11.6	3.4	-	40.13	25.5	-
Coleoptera	16.8	25	17.2	39	6.8	4	88	78.6	50	35.1	36.74	14.07	46.62	44.18
Diptera Larvae	2.7	4	12.8	29	-	33	64.3	-	0.35	0.94	-	12.01	26.01	-
Lepidoptera Larvae	11.4	17	5.7	13	1.7	1	33	50	16.7	7.1	4.76	9.01	17.16	20.15
Coleoptera Larvae	6.7	10	9.7	22	-	77	50	-	8.2	27.39	-	30.65	29.03	-
Neuroptera Larvae	0.7	1	0.4	1	-	11	7.1	-	-	-	-	3.9	2.5	-
Hemiptera (Immatured)	-	0.4	1	1.7	1	-	7.1	16.7	-	0.04	1.7	-	2.51	6.2

Note: MF: Females; MM: Males; MI: Juveniles; Numbers in bold: Sample size of each prey item

The first discriminant function (root) was weighted more heavily by the abundance of Orthoptera, Hymenoptera and Hemiptera (in order); 73.9% of all discriminatory power was explained by the first function having an eigenvalue of 4.60. This function clearly discriminated the group of females from that of juveniles.

The second function seemed to be marked mostly by the abundance of Gastropoda, Hemiptera and mean prey length (in order). 27.2% of all discriminatory power was explained by the second function with an eigenvalue of 1.63. This function mostly discriminated the group of males from the other two groups.

Of the 29 specimens classified, 83.3% of juveniles, 88.9% of females and 92.8% of males of *L. luschani basoglui* were correctly classified. The mean proportion of correct classifications was 89.6%.

On the scatter plot in Figure 1, three clusters were observed, and the corresponded to *L. luschani basoglui* age and sex groups (Figure 2).

A strong discrimination was recorded between female and juvenile salamanders, while the male cluster was intermediately separated from the other two.

4. Discussion

Insecta dominate in the diet of *L. luschani basoglui* in Kastellorizo, with Coleoptera being the most important order for matured males and females, and Collembola for juveniles. According to Düşen *et al.* (2004) the majority of the diet of *L. luschani basoglui* in Turkey was Insecta, and within Insecta, Coleoptera was the dominant order.

The number and the size of prey items consumed by males and females of *L. luschani basoglui* in Kastellorizo were quite similar, while juveniles ate fewer items of much smaller size. Statistical analysis showed clearly that prey size depended on body size variables of salamanders. On the contrary, the adults of *Aneides flavipunctatus*, a plethodontid salamander, took less prey than juveniles (Lynch, 1985).

Although no significant difference exists in body size between males and females, a clear discrimination of the two sexes based on prey taxa abundance and actual prey size was recorded. Our results are in agreement with Çiçek *et al.* (2007), who observed among others a weakly non-statistically significant difference between sexes of *Lyciasalamandra fazilae* in frequency of occurrence and volumetric proportion of prey taxa. In addition, Guerrero *et al.* (1990) and Düşen *et al.* (2004) did not observe any statistical difference in stomach contents with regards to the age and sex groups of *Salamandra salamandra*

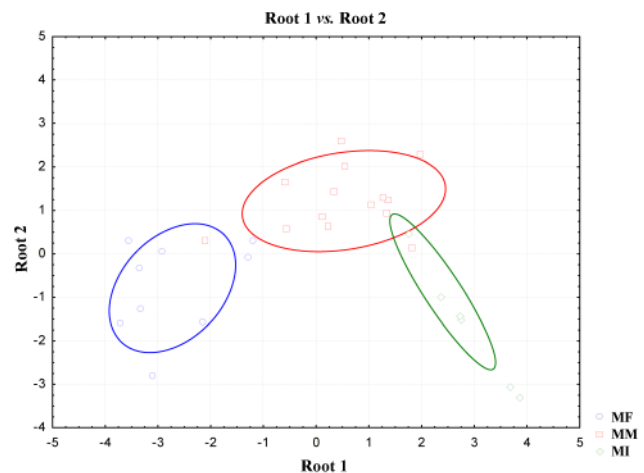


Figure 1 Discriminant function analysis (DFA) based on prey taxa abundance and actual prey size of the three age and sex groups of *L. luschani basoglui*. Note: MF: Females; MM: Males; MI: Juveniles



Figure 2 The Lycian salamander *L. luschani basoglui* in its biotope on the island Kastellorizo (Photo by K. Eleftherakos).

almanzoris and seven *Lyciasalamandra* subspecies.

Mitchell and Taylor (1986) found that although males and females of the salamander *Plethodon jordani* did not differ significantly in relation to the maximum prey length and the mean prey volume, a significant differentiation existed between sexes due to the mean prey length.

Terrestrial salamanders, as most salamandrids that have generalized feeding mechanisms, are active foragers with highly diverse diets (Duellman and Trueb, 1994). Thus, *L. luschani basoglui* is considered as an active opportunist predator (or a highly generalized and unselective predator on invertebrates) on diverse forms (Çiçek *et al.*, 2007; Polymeni, 1994). Another species of *Lyciasalamandra*, namely, *L. fazilae*, is also found to be active predator capable of changing its feeding regime in proportion to the species richness within its habitat (Çiçek *et al.*, 2007). The same fact is observed in the case of *Salamandra*

salamandra, the food spectrum of which is determined mostly by the abundance of prey from the habitat they occupy (Ferenti *et al.*, 2010). *S. lanzai*, a montane salamander distributing in northwestern Mediterranean region, proved to be also an opportunistic predator, feeding on invertebrates with a broad range of categories and sizes (Andreone *et al.*, 1999). However, Pyke *et al.* (1977) and Krebs (1978) noted that the optimal foraging behaviour of predators varies when they have a choice of prey differing in quality and/or varying in abundance, either temporally or spatially. A number of factors must be considered, such as different nutritional needs between growing young and adults, sex-related requirements (Donnelly, 1991), favourable conditions for feeding (Keen, 1979) and, probably, various morphometric variables of predators.

Our analysis reveals a contradiction: No significant difference was found in the overall diet composition among males, females and juveniles of *L. luschani basoglui*, while abundance and four measures of the actual size of prey taxa permitted discrimination among sex and age groups. To the best of our knowledge we are unaware of any previous studies revealing discrimination among sexes and age groups of *L. luschani basoglui* due to any diet or prey variable and, although *L. luschani basoglui* is a highly generalized and unselective predator on invertebrates (Polymeni, 1994), for the first time a strong discrimination is recorded among females, males and juveniles. Discrimination between adults and juveniles could be attributed to the dissimilarity of body size between these age groups (Baran and Ücuncü, 1994; Tzannetatos-Polymeni, 1986; Wheeler *et al.*, 2007). This dissimilarity is probably reflected on some variables of invertebrates preyed on.

A non-significant difference in the diet between male and female *Mesotriton alpestris*, *Triturus cristatus* and *Lissotriton vulgaris*, and all members of the Salamandridae, has been recorded by Covaciu-Markovi *et al.* (2010). However, the discrimination of males and females of *L. luschani basoglui* based on prey variables remains inexplicable taking into account the similarity of their body size. The level of activity of males and females as well as the cues mainly used for preying by each sex group should probably be examined in order to elucidate the discrimination found.

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